BUILDING AN ONTOLOGY AND PROCESS ARCHITECTURE FOR ENGINEERING ASSET MANAGEMENT

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Historically, asset management focused primarily on the reliability and maintainability of assets; organisations have since then accepted the notion that a much larger array of processes govern the life and use of an asset. With this, asset management's new paradigm seeks a holistic, multi-disciplinary approach to the management of physical assets. A growing number of organisations now seek to develop integrated asset management frameworks and bodies of knowledge. This research seeks to complement existing outputs of the mentioned organisations through the development of an asset management ontology. Ontologies define a common vocabulary for both researchers and practitioners who need to share information in a chosen domain. A by-product of ontology development is the realisation of a process architecture, of which there is also no evidence in published literature. To develop the ontology and subsequent asset management process architecture, a standard knowledge-engineering methodology is followed. This involves text analysis, definition and classification of terms and visualisation through an appropriate tool (in this case, the Protégé application was used). The result of this research is the first attempt at developing an asset management ontology and process architecture.

Keywords: asset management, ontology development, process architecture, text mining, classification.

1 INTRODUCTION

The proper management of physical assets remains the single largest business improvement opportunity in the 21st century [1]. Organisations from all around the world now collectively spend trillions of dollars in managing their respective portfolios of assets. Historically, asset management (AM) focused primarily on the reliability and maintainability of assets; organisations have since then accepted the notion that a much larger array of processes govern the life and use of an asset, leading to a significant increase in the amount of asset management literature being published (particularly since 2000) [2-5]. This can be attributed to the modern context of asset management - one that encompasses elements of: strategy; economic accountability; risk management; safety and compliance; environment and human resource management; and stakeholder and service level requirements [6-8]. These elements have previously existed as disparate departments (or silos) within an organisation and in many cases continue to do so; asset management's new paradigm seeks a holistic, multi-disciplinary approach to the management of physical assets – the foundation for the overall success of an organisation [9].

Although most relevant articles acknowledge that asset management requires a multi-disciplinary approach, their content continues to mostly focus on individual elements of asset management, thus essentially missing the objective of what an ideal asset management definition strives for. A growing number of organisations, however, *have* understood the definition and are now developing asset management bodies of knowledge and asset management frameworks, *i.e.*, high-level conceptual building blocks of asset management that bring together several disciplines into one overall process [7, 10]. Examples of such organisations include CIEAM [11], IAM [8, 12], AM Council [13] and IPWEA [14]. Such organisations are driving the development of new and extended asset management knowledge, incorporating the idea that asset management *must* be considered as a multi-disciplinary domain, *i.e.*, one that governs and streamlines many different areas of an organisation whilst guiding managerial personnel the necessary know-how to successfully implement and sustain asset management initiatives.

This research seeks to complement existing outputs of the mentioned organisations through the development of a fundamental, conceptual asset management ontology. Ontologies are content theories about the sorts of objects, properties of objects, and relations between objects that are possible in a specified domain of knowledge and provide potential terms for describing our knowledge about the domain of interest [15]. Ontologies define a common vocabulary for both researchers and practitioners who need to share information in a chosen domain [16]. As more and more information is published in the asset management domain, the importance of knowledge-based systems and consistent representation and vocabulary of such information is increased [17], thus supporting the argument for the building of an asset management ontology. To the best of the authors' knowledge, a holistic asset management ontology, *i.e.*, one that encapsulates the ideal definition of asset management, has not yet been published. By developing an asset management ontology, one can also realise the basic structure of an asset management process architecture. The architecture of the processes of an organisation is defined as the type of processes it contains and supports, as well as the relationships among them [18]. It has already been stated in literature that it is desirable to decompose asset management into a set of processes [19-27]. An asset management process is a set of linked activities and the sequence of these activities that are necessary for collectively realising asset management goals, normally within the context of an organisational structure and resource constraints [28]. No consistent asset management process architecture has yet been published.

To develop the ontology and subsequent asset management process architecture, a standard knowledge-engineering methodology is followed. This involves text analysis, classification of terms and visualisation through an appropriate tool (in this case, the Protégé application was selected). The result of this research is the first attempt at developing a fundamental, conceptual asset management ontology and process architecture. The developed ontology can be used to: share and annotate asset management information; identify gaps in current asset management thinking; visualise the holistic nature of asset management; classify asset management knowledge; and develop a relational asset management knowledge-based system.

This paper is structured as follows: background information on various topics is presented in Section 2; the methodology followed is presented in Section 3; the asset management ontology and process architecture is detailed in Section 4; analysis of results is shown in Section 5; and conclusions and directions for future research are given in Section 6.

2 BACKGROUND

Several research topics form the context of this research. This section presents a brief introduction to each topic.

2.1 The Evolution and Importance of Asset Management

Engineering asset management is a process of organising, planning and controlling the acquisition, use, care, refurbishment, and/or disposal of physical assets in order to optimise their service delivery potential and to minimise related risks and costs over their entire life. This is achieved through the use of intangible assets such as knowledge based decision-making applications and business processes [29, 30]. Previously, asset management was often a practice not dissimilar to pure reliability and maintenance, following the simplistic doctrine of cost saving. Now, however, many organisations have shifted views on asset management. The result is a new appreciation of the processes governing an asset, especially the integration of lifecycle costing into asset decisions. An asset typically progresses through four main life stages: create, establish, exploit and divest [2]. These four stages can be thought of as the value chain of an asset, and all must be optimised to deliver a better return on asset investment. Thus, engineering asset management is more than just a maintenance approach as it should influence all aspects of an asset's life [31]. It encompasses a broader range of activities extending beyond reliability and maintenance [32].

The prevalent view today is that properly executed engineering asset management can bring great value to a business [7]. It has been stated, that asset management is ultimately accountable to the triple-bottom-lines of a business [2], namely economic, environmental and social. It is also an increasingly important governance issue, as the scope of engineering assets expands. Asset management is continually developed to become an integrated discipline for managing a portfolio of assets within an organisation. Much, however, will still need to be achieved before it can become a standard process for a business [33, 34].

Godau et al. [35] sums it up well by saying: asset management needs to deal with a range of complexities born out of the increasing technological, economic, environmental, political, market and human resources challenges facing this generation and our future generations. A holistic approach must be undertaken in which all roles involved with the management of assets come together in a practical framework and organisational structure to achieve the desired results and performance. Strategic thinking into the future is critical to ensure that future generations receive adequate levels of service across all industries, disciplines and applications [36].

2.2 Text Mining as a Form of Information Analysis

Text is the predominant medium for information exchange among experts and is also the most natural form of storing information [37-39]. The knowledge stored in text-based media is now recognized as a driver of productivity and economic growth in organisations [40]. With this, text mining is at the forefront of research in knowledge analysis and discovery.

Text mining is a multidisciplinary field that encompasses a variety of research areas: text analysis; information extraction and retrieval; clustering and classification; categorization; visualization; question-answering (QA) database technology; machine learning; and data mining [39, 40]. In almost all cases, text mining initiatives rely on a computer due to the massive text processing required [37, 41]. However, it is difficult for a computer to find the meaning of texts because they often have different possible meanings [42, 43]. Other ambiguities that occur when analysing text are: lexical ambiguities (words having more than one class – verb and noun); syntactic ambiguities (parsing of sentences); and semantic ambiguities (meaning of sentence). Humans can generally resolve these ambiguities using contextual or general knowledge about the subject matter, as well as a thorough understanding of the English language. Much research and methodologies has been developed to increase the efficiency and correctness of text mining applications.

2.3 Using Ontologies to Organise Knowledge

In philosophy, ontology is the study of the kinds of things that exist in the world, including their relationships with other things and their properties [15, 44]. An ontology defines a common vocabulary for researchers and practitioners who need to share information in a domain in a consistent and agreed manner [16]. Although more prominent in Artificial Intelligence (AI) and Information Systems (IS) applications, many disciplines now develop standardized ontologies, *e.g.* SNOMED ontology in the medicine field [45]. As more and more information is published on a particular domain, the need for ontological analysis as a way to structure such knowledge becomes increasingly important.

One of the more commonly referenced definitions of an ontology is that of Gruber's [46] which states that ontologies are explicit formal specifications of the terms in a domain and relations among them. Noy and McGuiness expand on this by referring an ontology as a formal explicit description of concepts in a domain of discourse (classes), properties of each concept describing various features and attributes of the concepts (slots), and restrictions on slots (facets) [16]. Ontologies are used in many applications as mentioned in literature, for example:

- Sharing and annotation of information [15-17, 47, 48]
- Reuse of domain knowledge [16, 17, 47]
- Facilitate communication [48, 49]
- Natural language understanding and knowledge-based systems design [15, 17]
- Business process re-engineering [49]
- Artificial Intelligence (AI) and Information Systems (IS) [15, 47, 49]

Despite their applications, ontology development is still a challenging task [50], and it suffers from two main limitations: use of ontology and construction difference. Use of ontology refers to the notion that an ontology is unlikely to cover *all* potential uses[15]. Construction difference refers the notion that building an ontology is more akin to an art rather than a science, and that there is no single and correct methodology for building an ontology [16, 17, 48, 51]. There are however a variety of methodologies currently exist in literature, such as TOVE, Ontolingua and IDEF[5] [17,49,51].

2.4 Process Architecture

The architecture of the processes of an enterprise is defined as the type of processes it contains and supports, as well as the relationships among them [18]. It can be defined for the whole of an enterprise or for some portion thereof and is generally presented as a high-level diagram [52]. Several whole-of-enterprise process architectures currently exist (e.g. AQPC's Process Classification Framework [53] and the Zachman Framework [54]). However, they do not cover the scope of asset management at a sufficient level. A process architecture is a schematic that shows the ways in which the business processes of an enterprise are grouped and inter-linked. Developing a process architecture is generally seen as an important step in any process management initiative as it lays the framework for existing business processes, including the relationships among them. Therefore, interested personnel can view these business processes at varying levels of detail and scope, depending on their needs. In many cases, developing a process architecture becomes an iterative process as organisations understand more and more about their operations. Nevertheless, it is generally more appropriate to define the process architecture at an early stage of process management. Process architectures generally consists of several tiers (or levels) in a hierarchical orientation, with each tier describing more process detail than the tier before it. The first tier generally describes the overall, high-level, abstract activities that an organisation performs. The second tier generally describes the key processes that define an organisation and provide the mechanism for the implementation of the first tier elements. The third tier (and possible sub-tiers) generally describes individual, well-defined processes that are implemented in order to achieve the goals of an organisation. This tier is of much detail, with many meta-models available to increase the capability of an organisation in modelling this tier (*e.g.* ARIS [55]). The fourth tier (and possible sub-tiers) generally describes the individual, segmented activities that an organisation performs. These activities link together to make up processes.

3 METHODOLOGY

This section details the methodology followed in developing the fundamental and conceptual asset management ontology and process architecture. The overall methodology is shown in Figure 1, followed by the details of each phase.

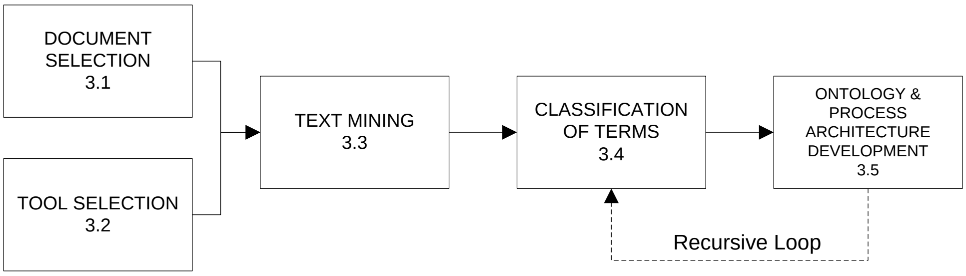

Figure 1: Flowchart depicting overall methodology for AM ontology and process architecture development

3.1 Document Selection

In order to conduct any text mining initiative, unstructured text (usually in the form of documents) must first be sourced. As the goal of this research was to develop a fundamental engineering asset management ontology, documents describing engineering asset management were first analysed. In total, over 100 articles (including journal articles, conference proceedings, books and practitioner publications) were scanned in order to find a suitable source, so as to establish a solid base for an asset management ontology and process architecture. The article that was ultimately chosen was the PAS 55 (Part 2) [12].

In 2004, the Institute of Asset Management (IAM) [8, 12] published, in two parts, PAS 55 – a publicly available specification document. It was developed in response to demand from industry for a standard for carrying out asset management. The first part details the specification, whereas the second part details the guidelines for applying the first part. PAS 55 centres on a core concept that an asset management system consists of five stages/phases: policy and strategy; asset management information, risk assessment and planning; implementation and operation; checking and corrective action; and management review. The specification then details what an organisation should have in their current asset management practice. Currently, the document is being used to certify organisations that prove their effective asset management practices through gap analyses. The PAS 55 can be thought of as a checklist of asset management elements that an organisation needs to adopt to improve their management of physical assets. The specification was developed by a large body of agencies, and in some ways is considered to be a quasi-standard (BSI standard) in asset management. The manual is not meant to be prescriptive as direct instructions, thus making it open to interpretation. There are also no individual quality weightings for the elements discussed, thus it is not easy to gauge exactly how to best apply PAS 55. It does, however, give a very good high-level view of asset management (holistic) and can be of great benefit to organisations looking to improve their asset management processes.

There are several reasons for choosing PAS 55-2 document. Firstly, the document is itself a summarised snapshot of engineering asset management, describing the essential elements of an effective and suitable asset management system. This means that the text contained within the document is more focused as compared to some of the other texts. Secondly, PAS 55 was developed by a large consortium of practitioners practicing asset management, as well as having gone through extensive review and update phases. PAS 55 is now being used to benchmark an organisation’s asset management initiatives, to see whether the organisation is implementing the required elements of asset management. PAS 55 has received mostly positive feedback and uptake by industry, and is the first step towards a more rigid standard in engineering asset management.

3.2 Tool Selection for Ontology Development

Protégé is a free, open-source platform that provides a growing user community with a suite of tools to construct domain models and knowledge-based applications with ontologies. At its core, Protégé implements a rich set of knowledge-modeling structures and actions that support the creation, visualization, and manipulation of ontologies in various representation formats. In particular, the Protégé-Frames editor was used as it enables users to build and populate ontologies that are frame-based, in accordance with the Open Knowledge Base Connectivity protocol (OKBC). In this model, an ontology consists of a set of classes organized in a hierarchy to represent a domain's concepts (in this case asset management), a set of slots associated to classes to describe their properties and relationships, and a set of instances of those classes - individual exemplars of the concepts that hold specific values for their properties. Protégé is one of the most common tools available to build ontologies, and as it was not the goal of this research to evaluate various ontology development tools, Protégé was selected due to its broad support base and ease of use [56].

3.3 Manual Text Mining

The PAS 55-2 document's main content is 36 pages in length (reference Sections 4.2-4.6). A manual text mining/analysis approach (as opposed to using a computer text mining application) was utilised due to this relatively small document length. The second reason for choosing a manual approach was so that contextual information could also be captured. As mentioned previously, computers are unable to visualise contextual information as well as humans reading the same passage of text. Both contextual information and experience in using the English language are positive arguments towards using a manual text mining approach. This, however, only applies if one has a small amount of text to analyse. Most text mining applications use many source documents. In these cases, a manual text mining approach cannot realistically be utilised.

When text mining a source document, an analyst essentially scans for three open word classes, namely: nouns, verbs and adjectives. Other word classes can also be utilised, but as it was the intention to extract only the key terms of asset management (for ontology), these three word classes were sufficient. To recall general knowledge: nouns give names to persons, places, things and concepts in general; verbs is the class of words used for denoting actions; and adjectives are words used to modify the noun [57]. Extracted terms were placed into the following format: noun (adjective$_1$…adjective$_x$). As expected, at the start of the text mining activity, many terms were continually being added to the list (implemented in Excel 2007). As the activity continued, it was found that less and less terms were added as they already existed in the listed, but rather, adjectives were being added to the list where text described a particular concept from another contextual point-of-view. Verbs, in this case, were used purely for realising and supporting the context of any particular passage(s) of text. From the 36 pages of text scanned, a total of 1193 individual terms were manually extracted.

3.4 Classification of Terms

The terms extracted from the previous step, were then classified into several categories of terms, following the ARIS architecture methodology, *i.e.*, the ARIS house concept [55], and in particular, the EPC modelling convention [55]. The EPC (event-driven process chain) notation is a process modelling notation that is composed of the following rudimentary elements:

- Event – passive trigger points for a process or function (or activities)
- Function – fundamental activity as performed by an agent
- Organizational unit – agent performing the activity (e.g. person)
- Resource object - physical objects that exist in the world which are utilized by a function and/or an organizational unit
- Information system object – information systems-related objects as utilized by a function and/or an organizational unit

As there was no distinct separation between functions and processes (functions being the constructs of a process), "process" was used as the category to describe a procedure the organization performed. The final categories used were as follows: AM EVENT, AM ORGANIZATIONAL ENTITY, AM RESOURCE ENTITY, AM INFORMATION SYSTEM ENTITY and AM PROCESS. These categories form the most upper elements of the ontology which equate to what objects exist in the asset management domain. The selection of these elements also aids in creating actual process chains in the EPC notation (a commonly adopted notation in the process management domain). In this case, the ontology represents the process architecture as part of its composition.

3.5 Ontology and Process Architecture Development

An ontology is an explicit account or representation of some part of a conceptualisation, a collection of terms and definitions relevant to business enterprises [58, 59]. Ontologies are generally created for specific applications, and in some cases domains, however, their creation is still generally considered to be an art, rather than a science [17]. Several methodologies for ontology development currently exist in literature, such as in [16, 17, 46, 47, 49, 51, 56, 59-62]. In most of these literatures, a generic skeletal methodology for ontology development is proposed, and is as follows:

- Identify a purpose for the ontology (determines the level of formality at which the ontology should first be described).
- Identify scope (a specification is produced which fully outlines the range of information that the ontology must characterise).
- Formalisation (create the code, formal definitions and axioms of terms in the specification).
- Formal evaluation (generally includes the checking against purpose or competency questions specific to a particular ontology).

In [59], these generic steps are discussed in further detail. For example, formality refers to an ontology being either: highly information (expressed loosely in natural language); structured information (expressed in a restricted and structured form of natural language, greatly increasing clarity by reducing ambiguity); semi-formal (expressed in an artificial formally defined language; and rigorously formal (meticulously defined terms with formal semantics, theorems and proofs of such properties as soundness and completeness). There are also several purposes to an ontology (mentioned briefly in an earlier section). These are: communication (between people); inter-operability (among systems achieved by translating between different modelling methods, paradigms, languages and software tools); systems engineering (including re-usability, knowledge acquisition, reliability and specification). An ontology can also be generic, that is, can be reused in a range of different situations. In terms of asset management, as per this application, the ontology developed is unambiguous, but an informal ontology. This is because the focus of this research is not the inter-operability of information systems, but rather the systematic and consistent approach to developing asset management process patterns. The subject matter, is the third element of an ontology. Three widely accepted categories are:

- Whole subjects (*e.g.* medicine, geology, finance)
- Subjects of problem solving
- Subjects of knowledge representation languages

The first category is generally the most popular one and is frequently referred to as a domain ontology. Overlap between these categories is generally encountered due the difficulty in scoping an ontology perfectly. In this paper, the developed ontology is an asset management domain ontology. The methodology implemented for developing the initial asset management ontology is presented below, followed by more specific details of each step:

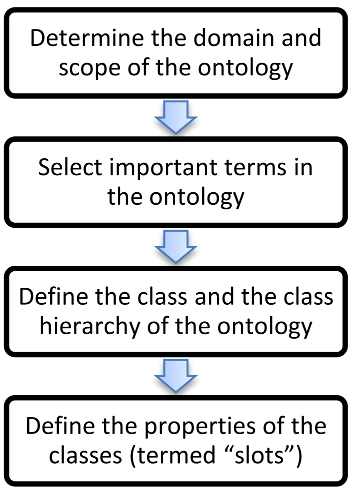

Figure 2: Ontology development methodology (using [16])

Defining the domain and scope of the ontology: As it was mentioned earlier, the ontology developed as part of this research is for the asset management domain, the scope being that as implemented by the PAS 55-2 document. There is a perceived lack of clear understanding in literature of what processes and elements make up the modern context and understanding of asset management.

Selecting important terms in the ontology: The extraction and classification of terms as outlined in Sections 3.3 and 3.4 ensured that the most important terms were selected from the document. As the document itself was a summary of asset management, as expected, a high percentage of terms were in fact considered to be important towards the ontology.

Defining the class and class hierarchy of the ontology: A combination development process was used to develop the class hierarchy of important terms. The upper most classes were chosen as: AM EVENT, AM ORGANIZATIONAL ENTITY, AM RESOURCE ENTITY, AM INFORMATION SYSTEM ENTITY and AM PROCESS. A combination process is one where several top-level concepts are first selected, followed by the recursive process of placing both lower-level and middle-level elements into the class ontology. Thus, a combination approach is the combination of a top-down approach (high-level concepts first, then lower-level concepts) and a bottom-up approach (group the most specific elements first, then generalize into more abstract constructs). When developing the class hierarchy, the following rule was applied to ensure consistency among classes:

If a class A is a superclass of class B, then every instance of B is also an instance of A

Defining the slots of the classes: Slots define the internal structure of concepts of classes. Thus, slots are the internal properties of individual classes (relation). For this research, although slots were inputted into Protégé, they were not given values or ranges, rather being described simply as strings/words having no values set.

4 ASSET MANAGEMENT ONTOLOGY AND PROCESS ARCHITECTURE

Due to the size and layout constraint of this paper, the full presentation of the ontology and process architecture is not feasible as hundreds of classes and slots were identified from a single (short) document. Particular extracts of the ontology and process architecture are presented with accompanying details.

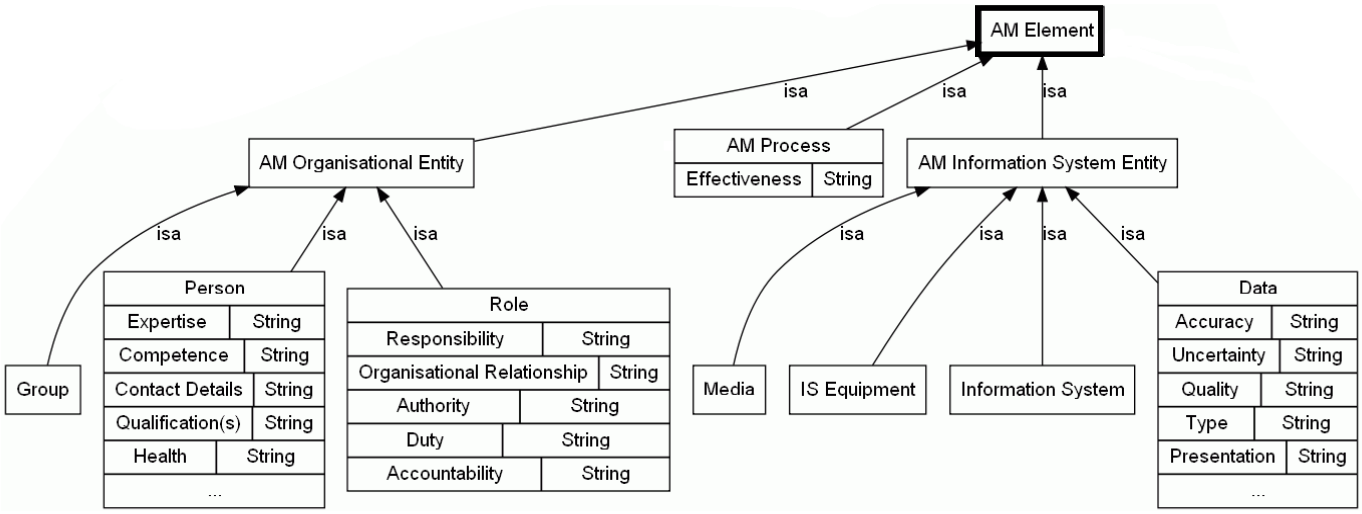

Figure 3: Upper-level AM ontology elements (part A)

The diagram in Figure 3 shows the partial upper-level AM ontology (one superclass): AM RESOURCE ENTITY. This class describes a physical object that is used by (input or output) an activity/function/process to enable the activity/function/process to complete – in many cases, the object is modified (e.g. an asset is repaired. There are four sub-classes in this case: asset, asset system, asset-related resource (e.g. spares/inventory), and AM document. Each class (both super and sub) can have a slot associated with it. As mentioned previously, a slot describes certain properties of a class. As an example from the above diagram, an asset can have the property of "performance target" with an associated value or value range (in this case this is simplified and limited to just being a string value, however, quantitative values can also be put here in place).

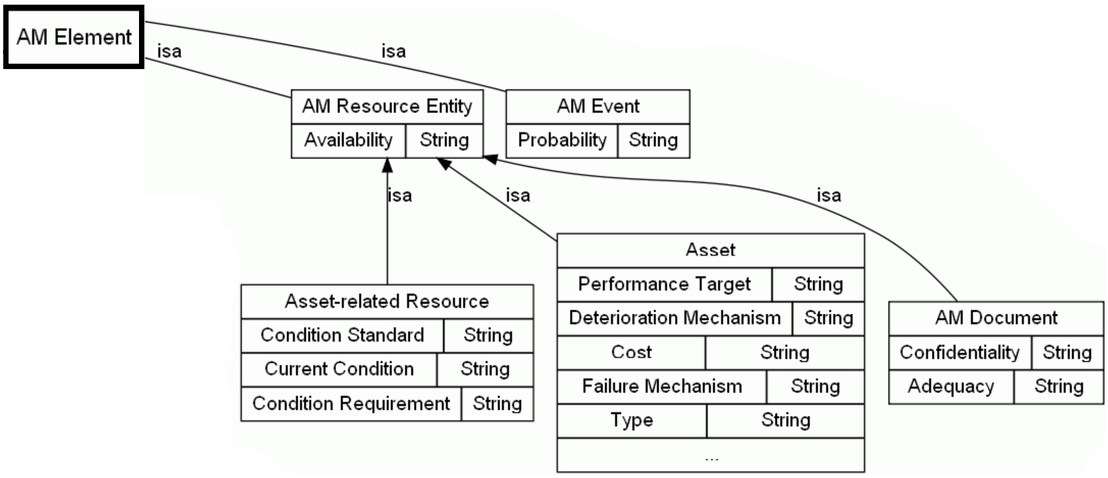

Figure 4: Upper-level AM ontology elements (part B)

Continuing on from the diagram in Figure 3, Figure 4 shows the remaining superclasses of the developed ontology, namely: AM ORGANIZATIONAL ENTITY, AM EVENT, AM INFORMATION SYSTEM ENTITY and AM PROCESS. It can be seen that the more slots that are developed, the more defined a class can become. By putting exact values into the slots and slot ranges, instances of classes can be created. For example, a specific PERSON in the organization will have a particular set of values for the slots *competence*, *expertise*, *qualifications* and so on. By becoming an instance of a class, the element becomes more succinct and less abstract. The same goes for the ROLE class. A specific role will have the slot properties filled in. A major ability of a detailed and comprehensive ontology is the ability to do relational statements. For example, if the ROLE class had a slot called *required qualification* and an instance of the PERSON class had a specific qualification value filled in, the following statement could be made: if *qualification (property)* of instance of PERSON class is equal to or greater than *required qualification (property)* then instance X is suitable for role Y. The figure below shows how a particular instance is represented within an ontology (in this case a specialist asset designer is chosen for illustrative purposes only).

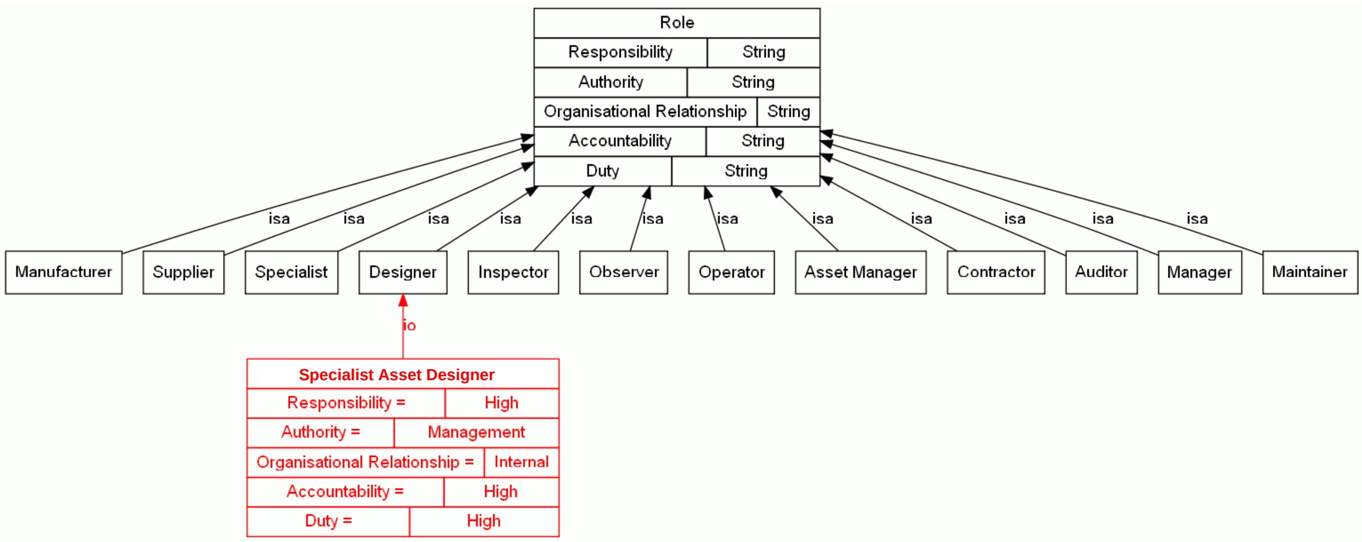

Figure 5: Example of instance of class representation

The arbitrary values of *high, management and internal* are chosen only to illustrate how an instance is represented within an ontology and its relationship with its parent class. As an ontology is filled in to a more defined (deeper) level, more and more instances would be enacted, with the super/parent classes remaining in an abstract form.

The diagram in Figure 6 shows an extract of the process architecture (as per the source document). It shows how the levels discussed in Section 2.4 are actually enacted. As this is only a minimal extract, many processes are obviously missing.

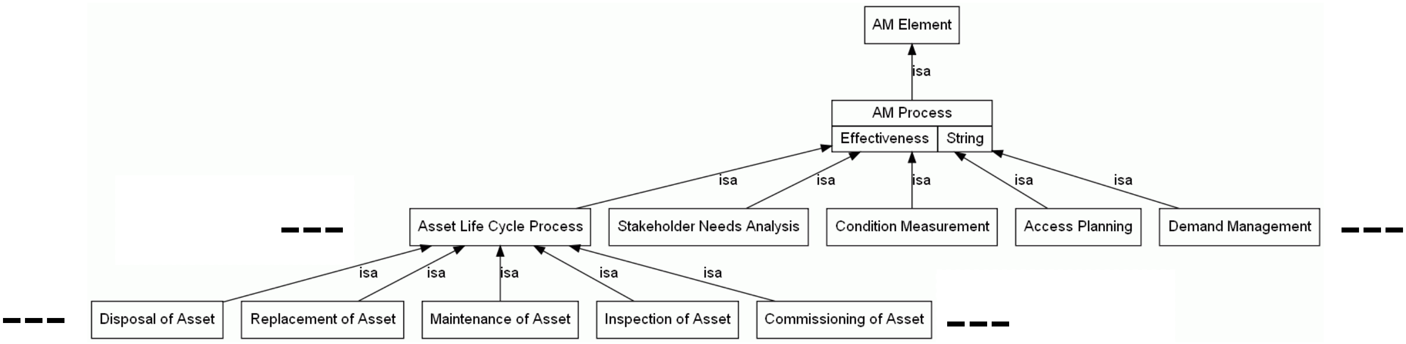

Figure 6: Extract of AM process architecture

Each element describes a particular process, which can then be further subdivided into sub-processes, and so on – thus forming the exact definition of what process architecture is. Each process element therefore follows the same principles as those discussed earlier in regards to instances of classes.

5 ANALYSIS OF RESULTS

No existing ontologies were found that encapsulates the real-world objects existing in the asset management domain. Asset management processes, despite being classed as important in to the asset management community, have received limited focus in research. Asset management is composed of many processes which organisations implement, manage and reuse constantly in real-world asset management operations. It is logical to identify these processes and present them in a systematic and efficient manner, which supports reuse in industry. With the lack of explicit asset management ontologies and process architectures currently in literature (in many cases processes are implied), a direct comparison with an existing ontology and process architecture was not possible. Ontology literature suggests reusing existing literature when possible (or at least modifying it). This paper set out to develop a first-draft, fundamental asset management ontology, as well as showing that this is in fact possible and beneficial. Using only one source document, however, limits the scope and rigour of the results. Although PAS 55-2 was found to be a solid summary of asset management, there are other elements covered in other sources that are absent. With this, more source documents must be chosen so as to enable a broader scope of asset management to be captured.

Through the analysis of existing asset management literature (other than the PAS55-2 document) it is clear that asset management suffers from inconsistent terminology, possibly stemming from its multi-disciplinary origin and general complexity in application. Thus, it is envisioned that a manual text mining methodology with several source documents should be utilised, rather than computer-aided text mining. Contextual information that can be captured in slots and instances of classes may be overlooked by using a computer for the analysis of text. An iteration process should also be used to enable the addition and elimination of terms/classes/instances/slots when necessary. In its current form, the developed ontology (and process architecture) builds a solid base for future additions and modifications, including the implementation of feedback from industry. By building a more rigorous ontology, relational statements can be utilised, which will lead into the development of an asset management knowledge system/base.

6 CONCLUSION

This research presents the methodology and development of an initial and fundamental asset management ontology and, subsequently, an asset management process architecture. The results show that an asset management ontology and process architecture can help support an organisation's asset management initiatives through consistent knowledge representation, knowledge-based systems development, process representation and improvement, process benchmarking and process compliance checking. The developed ontology consists of hundreds of classes and slots, having been extracted and classified from a single article (PAS 55-2). This research illustrates how an ontology can benefit the asset management community through common representation of key terms and their relationship to each other. Future work in this area should see the inclusion of additional terms into the developed asset management ontology so as to build a more comprehensive asset management ontology.

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